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Thermal Tuning of a Microwave Water-Based Metasurface

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Introduction – Fluidic metamaterials (MMs) have received increasing interest with their tunability and promising applications such as material sensing, bio-detection, imaging etc. [1]. With its relatively high permittivity [2, 3], water introduces many tuning-variables into MMs for dynamic control of their response. It has been shown that water-based MMs can be tuned thermally, chemically and by reshaping/deforming of as well as partially filling their containers [4, 5]. Water-based metasurface (MS) absorbers are investigated heavily, where lately one had a 90% absorption from 20 – 40 GHz [6]. In [7], we studied a MS capable of switching between reflecting and transmitting the incident power through 90° rotation of the MS. Furthermore, stacking several of these MSs effectively increased the switching efficiency. Presently, we continue the study of the same MS by investigating its thermal tunability.

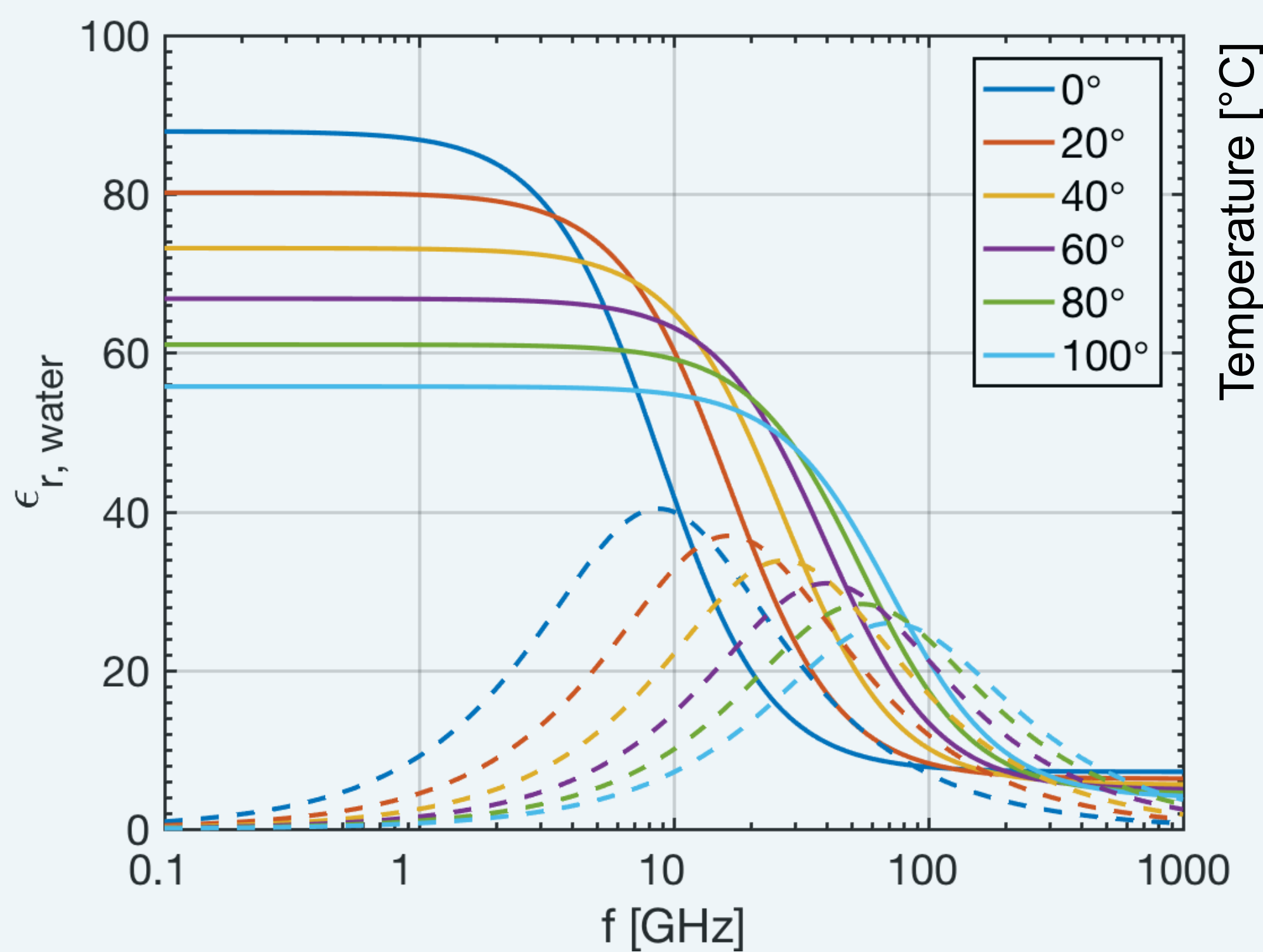


Fig. 1

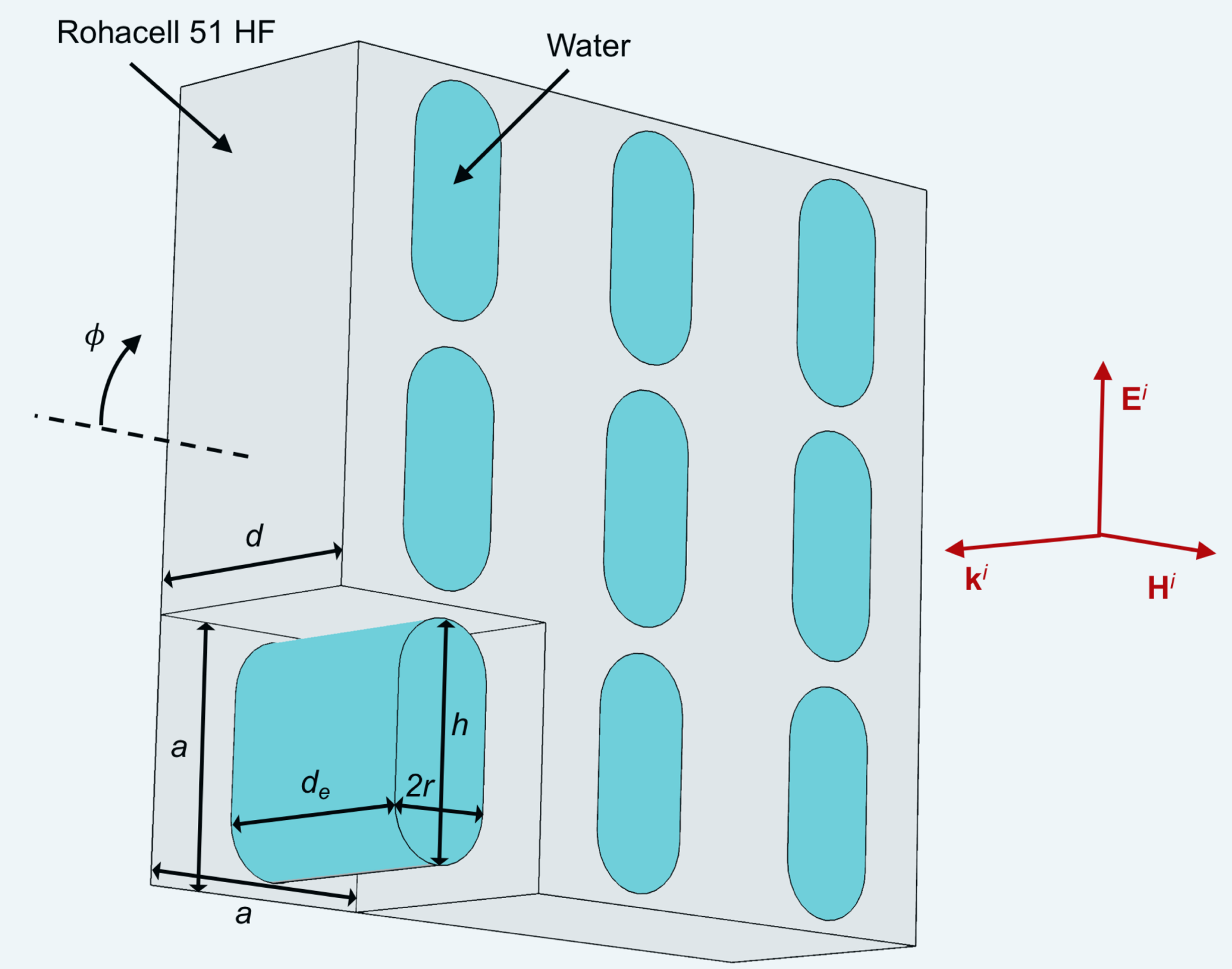


Fig. 2

Water has a relatively high dielectric constant and low losses from DC up to L-band at room temperature (Fig. 1). In X-band, the losses are highest and the dielectric constant is halved. **Increasing temperature** lowers the permittivity and blue-shifts the spectrum depicting the thermal tuning range. To minimize losses, the MS has to be designed for low frequencies and high temperatures. The thermal volume expansion of water is omitted in this work.

The MS consists of infinite water inclusions in a Rohacell 51 HF host (Fig. 2). The water inclusions are rounded rectangular cuboids. The geometrical parameters are $a = d = 50$ mm, $r = 10.7$ mm and $h = d_e = 45$ mm and angle ϕ describes the rotation of the MS. **It is designed** to function at 800 MHz as a mechanical switch by 90° rotation successfully blocking/transmitting a plane wave at normal incidence. The MS is implemented into COMSOL Multiphysics.

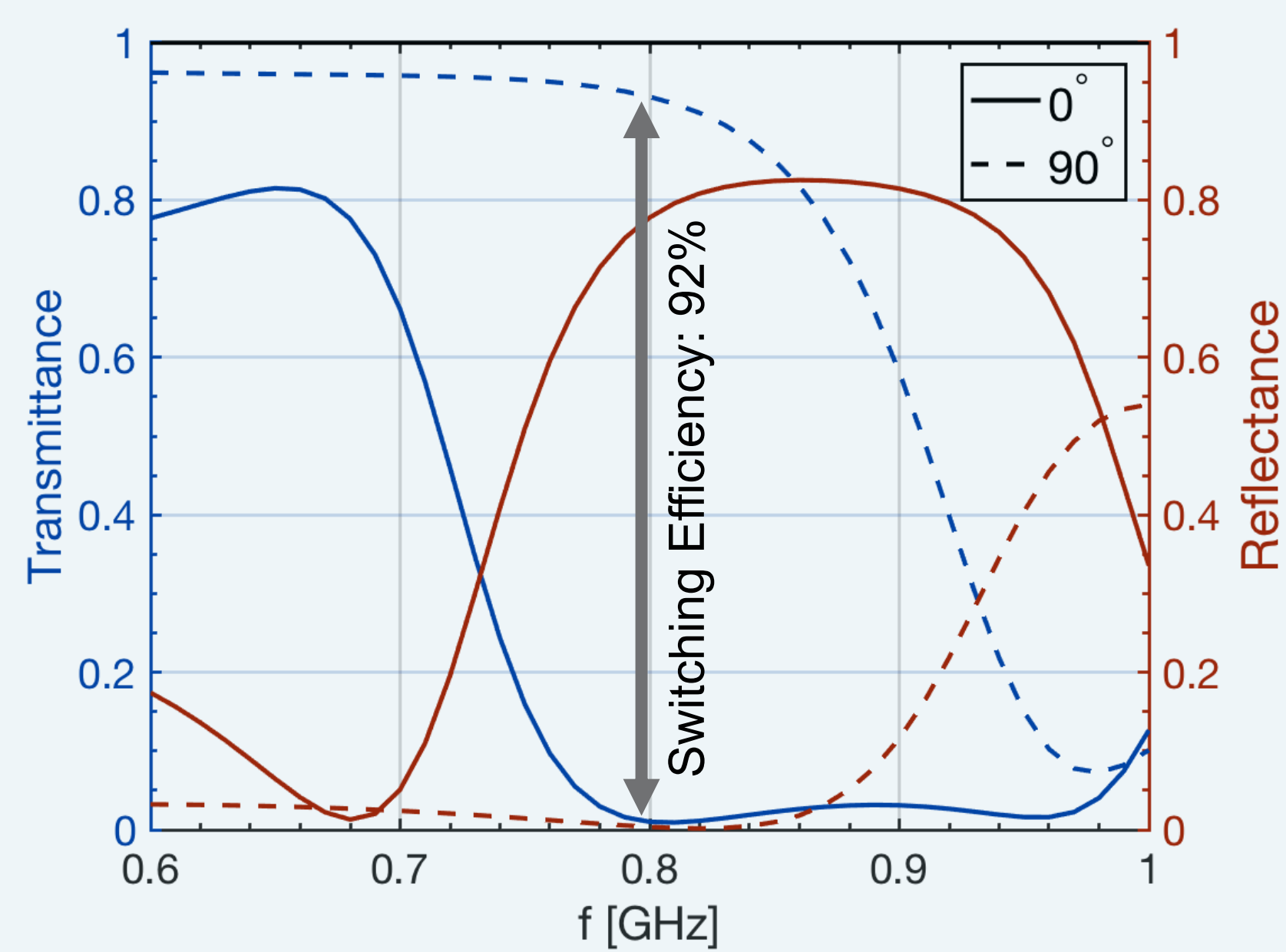


Fig. 3: 20 °C.

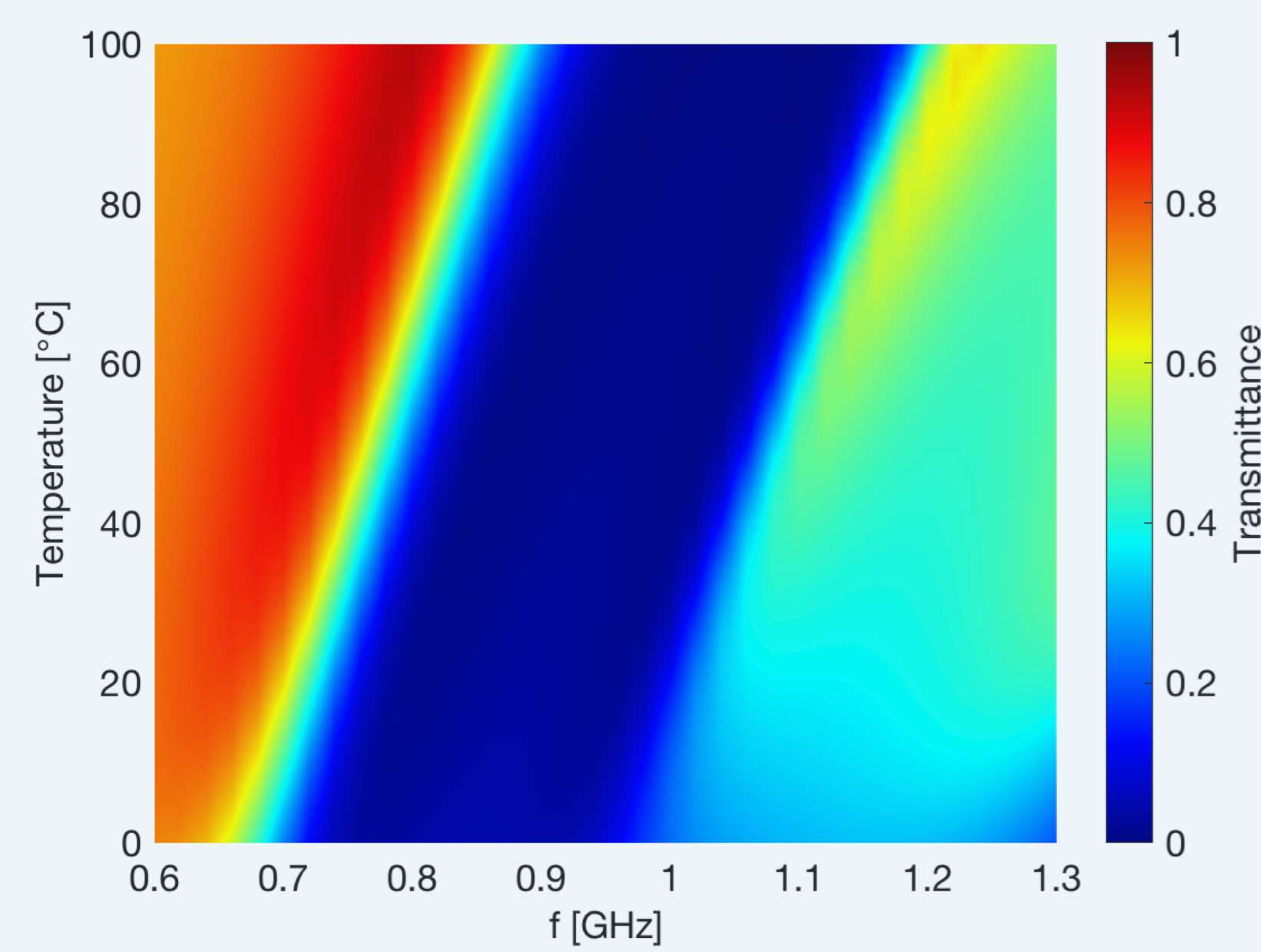


Fig. 4: $\phi = 0^\circ$.

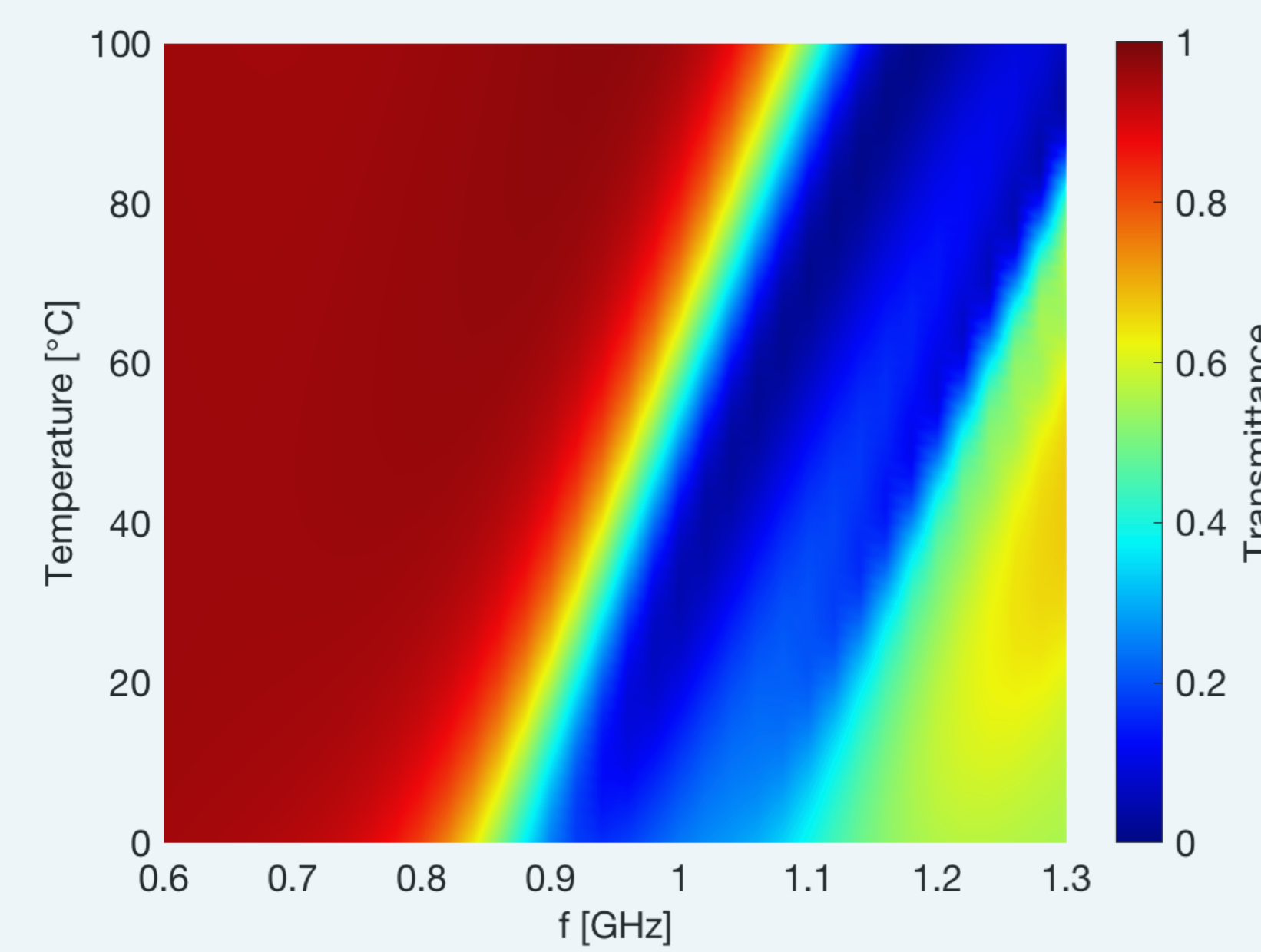


Fig. 5: $\phi = 90^\circ$.

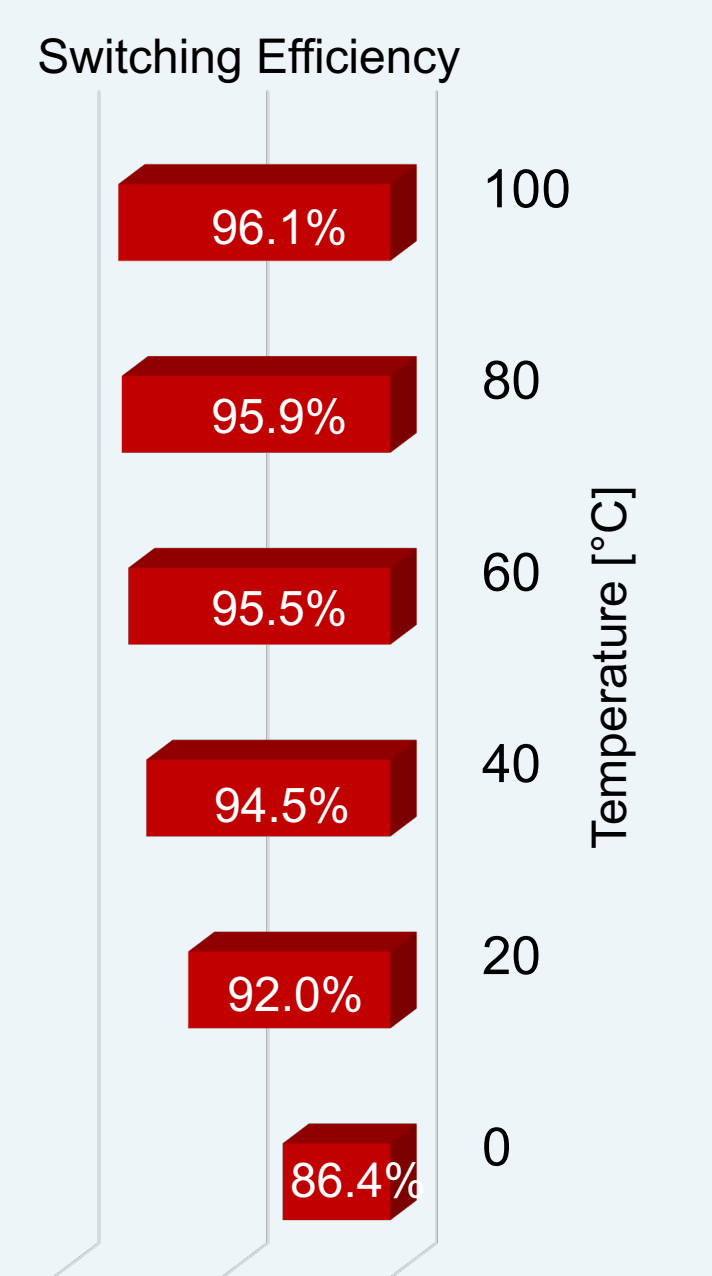


Fig. 6

Transmittance and reflectance describe the performance of the MS. At 800 MHz, temperature of 20 °C and $\phi = 0^\circ$, the transmittance is 1 % and reflectance 78 % (Fig. 1) due to magnetic resonances excited in the water inclusions [7]. Rotating the MS 90°, switches the transmittance to 93 %.

Changing the temperature effectively lets us tune the MS (Fig. 4: $\phi = 0^\circ$ and Fig. 5: $\phi = 90^\circ$). Like the permittivity of water, the spectrum is blue-shifted and

the thermal tuning capability is 220 MHz (29%) with a temperature increase from 0 – 100 °C. At higher temperatures, the switching efficiency is higher due to lower losses (Fig. 6), which is preferred in low-loss applications. From 60 – 100 °C, the switching efficiency only increases by 0.6%.

Heating may be provided by light, microwaves, chemical reactions, radio-activity, mechanical friction and passing electrical current through resistors.

Conclusions – The thermal tunability of a water-based MS functioning as a mechanical switch was investigated showing a frequency shift of around 29% (220 MHz) of the spectrum by a temperature increase from 0 – 100 °C. The tuning had a minor impact on the performance. The proposed water-based MS can be a controllable cost-effective and bio-friendly component within microwave applications.

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